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IMPACTS OF EROSION ON WASTE DUMP SLOPES AT THE JACKPILE-PAGUATE MINE CIBOLA COUNTY, NEW MEXICO

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I. INTRODUCTION

Mining activity at the Jackpile-Paguate Mine, a mostly open-pit uranium mine operated by the Anaconda Minerals Company (Anaconda) on the Laguna Indian Reservation in Cibola County, New Mexico, commenced in 1953 and ceased in early 1982. Anaconda submitted a reclamation plan (revised) on March 16, 1982. It has been determined that reclamation of the mine-site will be a major federal action significantly affecting the quality of the human environment, and therefore, an Environmental Impact Statement (EIS) is being prepared by the Minerals Management Service (MMS). Concern over susceptibility of waste dumps to accelerated erosion due to steep, long slopes has led to this analysis of waste dump slope erosion prepared as background documentation for the EIS.

There are 32 waste dumps at the Jackpile-Paguate Mine; their locations are given in Figure 1. Records detailing the type, percent, and radiological content of material in each dump do not exist. Several relatively flat dump tops have been reclaimed with success, however, reclamation attempts on slopes have been failures. Smith (1981) described the existing conditions at the dumps and found that the severity of erosion on dump slopes dictates that, unless significant slope modifications are made, revegetative success is unlikely. Reduction in slope angle and increase in surface roughness were seen as the modifications crucial to successfully inhibiting erosion.

Numerous methods designed to minimize erosional soil loss have been employed on sloping land surfaces under different conditions. Basically, these methods fall into one of 5 categories:

1. <u>Decreasing slope angle.</u> This acts to decrease the kinetic energy of moving water, thereby decreasing erosion.
2. <u>Decreasing slope length.</u> This diminishes the volume of flows, thereby decreasing erosive power.

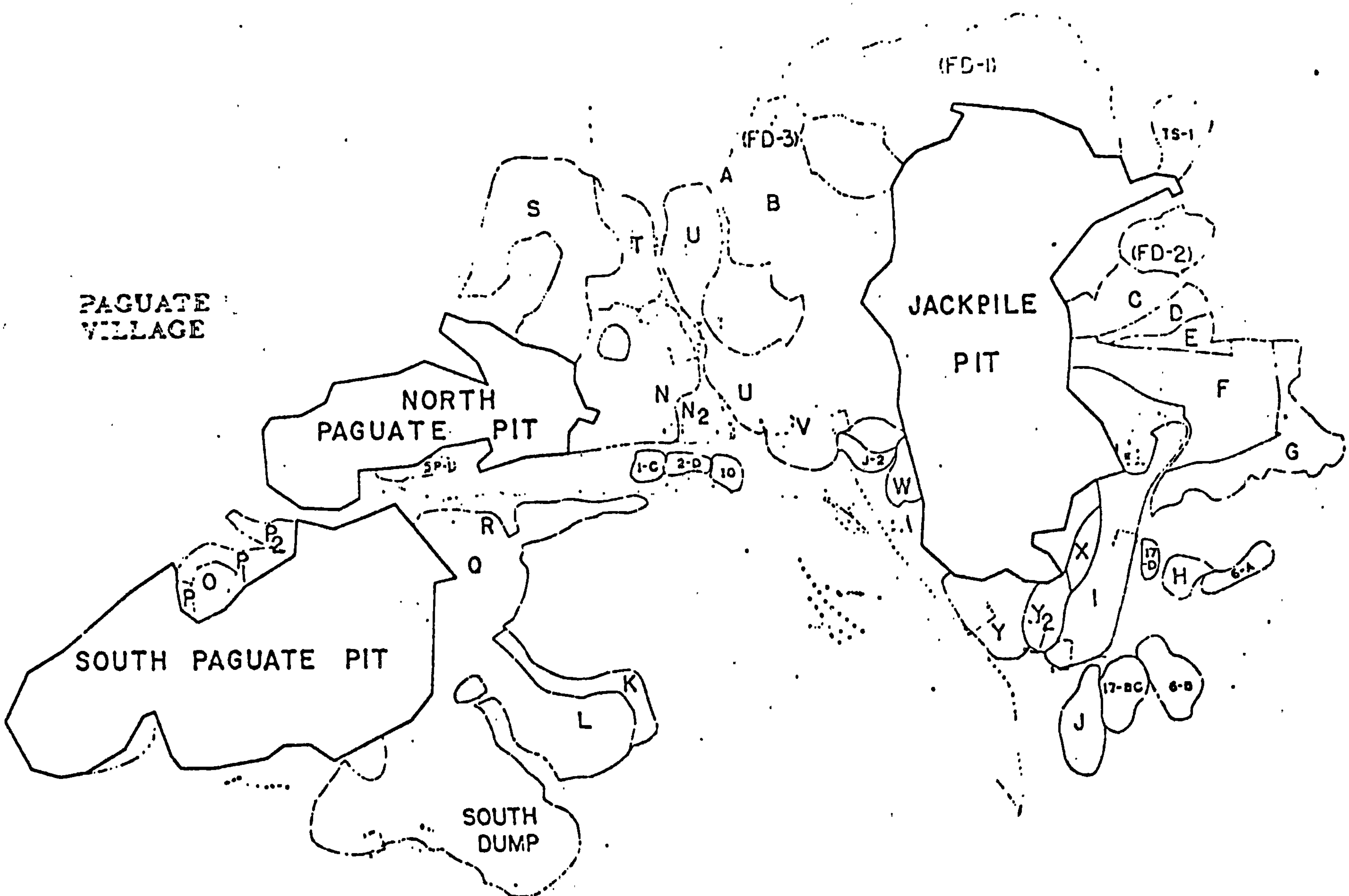


FIGURE 1 - Waste Dump Locations at the Jackpile-Paguate Mine

3. Increasing surface roughness. Rough surfaces intercept and divide water flows, thereby dissipating energy and subdividing the slope into smaller lengths.

4. Increasing water retention. This decreases the volume of flow. Examples: use of sandy soil, erosion control pitting, and contour furrowing.

5. Increasing soil cover. This reduces rainfall impact and may anchor soil. Examples: vegetation, mulch, rocky surface.

Regulations require that EIS's assess the impacts of all reasonable alternatives. The five alternatives to be assessed in the Jackpile-Paguate EIS are: 1) no action, 2) sacrifice area, 3) Anaconda's plan, 4) Task Force alternative, and 5) maximum site use proposal. As they relate to erosional issues, the no action and sacrifice area alternatives are identical as are the Task Force alternative and the maximum site use proposal. Therefore, this report will assess the impacts of waste dump slope erosion generated from no action (existing conditions), Anaconda's plan, and the Task Force alternative.

II. DESCRIPTION OF THE PROPOSED ACTIONS

The following will describe the specifics of Anaconda's proposal and the Task Force alternative. The details of existing conditions on waste dump slopes have been previously outlined (Smith, 1981).

A. Anaconda's Proposal

A detailed description of Anaconda's proposal is given in their revised reclamation plan (Anaconda, 1982) submitted March 16, 1982. As related to waste dump slopes, the proposal consists of the reduction in slope angle and length, coverage of dumps with topsoil material, removal of some dumps, DRAFT

construction of erosion control berms, and revegetation.

Dumps H and J would be relocated in open pits as backfill material. Dumps T, N, N2, and U would be moved back from the Rio Moquino so that a waste-free, 200 foot wide zone would exist on both sides of the river. Dumps FD-1 and FD-3 would be moved back 200 feet from the arroyo bordering them on the north. Protore stockpiles are to be used for backfill material in the pits.

The reduction in slope angle and length planned for most dumps would be accomplished mostly by removal of material to be used for backfill, although plans call for the pushing out of the dump toes in several dumps. Terracing of dump slopes would reduce most slope segment lengths to 100 to 200 feet. For most dumps, the long slope segments are planned for the upper part of the slopes, while the slope segments at the toe are mostly planned to be 30-80 feet long (e.g., Fig. 2). The longest slope planned is to be 480 feet long at a 3 (horizontal): 1 (vertical) angle on A and B dumps. Most non-terraced slopes are planned for 2:1, although several are planned for 3:1. Terraced slopes, the majority of slopes planned, would be constructed at 2:1 to 2.3:1, with most planned at or near 2:1. Several dump slopes (C, D, E, F, G, K, L, P1, P2, S) designated by Anaconda as reclaimed are planned for 1.5:1 angles. Five-foot high erosion control berms are planned for all dump crests and terraces and also at the toes of dumps T, N, N2, and U along the Rio Moquino. Open chute, rock-lined drainage structures are planned to drain water from dump crests and terraces.

Dumps that contain hazardous material on their outer surface would be covered with four feet of non-hazardous material and one foot of topsoil. Dumps that do not have an outer surface of hazardous material would be covered with one foot of topsoil. Fertilization will be followed with discing and use of compactor rollers - where conditions dictate to break up the soil. Seeding is planned to be accomplished mostly by rangeland drilling with some seeding

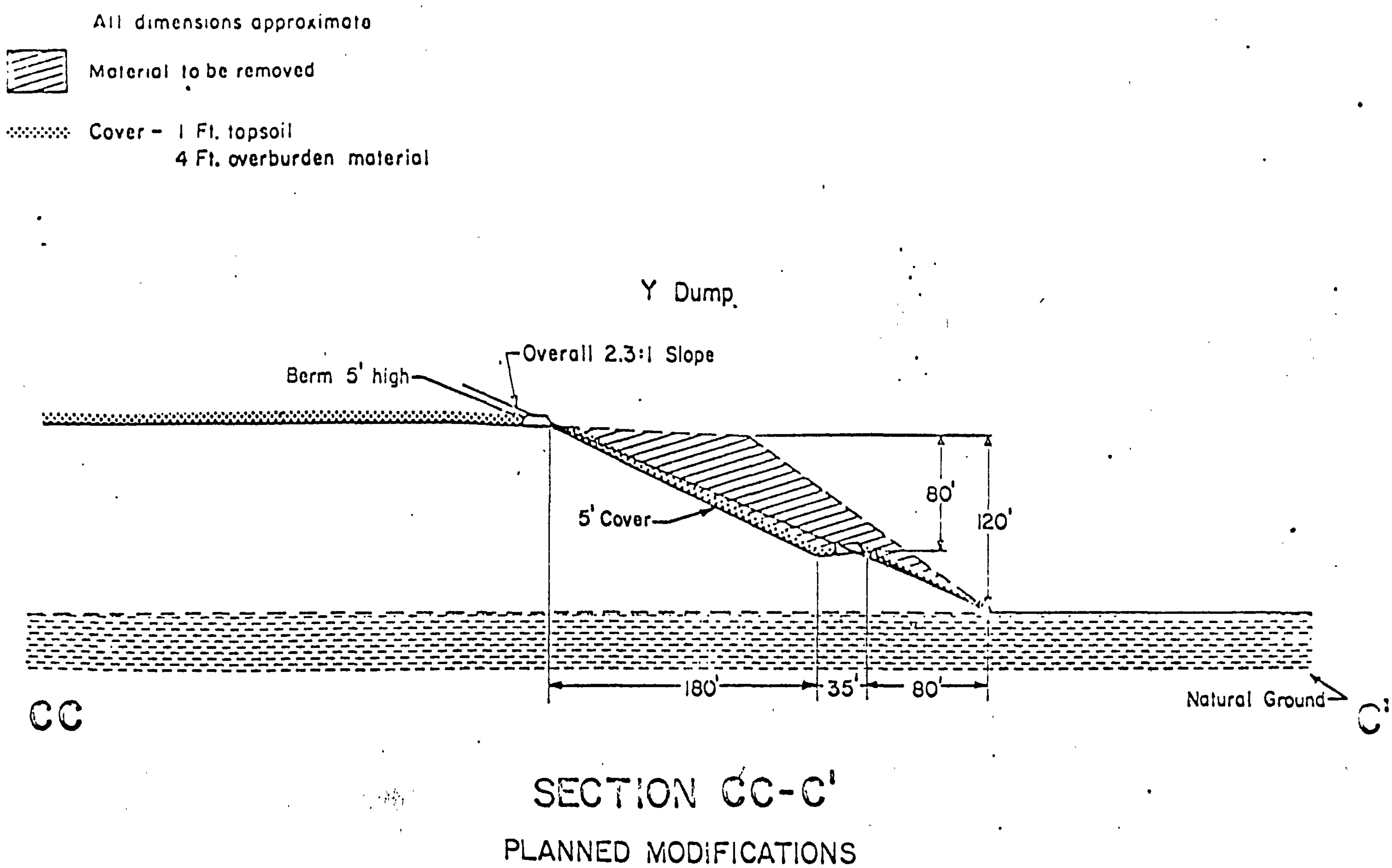


Figure 2. Typical terraced slope design under the Anaconda plan.

done by broadcasting methods. Mulch would be applied at two tons per acre and crimped into place. Bouldery material would be applied to slopes to the greatest extent practicable. Hydromulching and broadcast seeding will be utilized on areally restricted "tight spots" where machinery can't operate and on slopes that are too rocky or locally steep. Irrigation is not planned.

B. Task Force Alternative

In regard to dump slope reclamation procedures, the Task Force alternative is substantially the same as Anaconda's proposal, however, in general, the Task Force alternative includes more erosion mitigation procedures. Reduction in slope angle, berming techniques, contour furrowing, removal of some dumps, topsoil coverage, and revegetation are the major features of the alternative.

Dumps H and J will be moved to the pits to be used as backfill as will all protore stockpiles. Dumps T, N, N2, and U will be moved back 200 feet on either side of the Rio Moquino. Dumps FD-1 and FD-3 will be moved back less than 120 feet (as opposed to a 200 foot movement under Anaconda's plan) away from the bordering arroyo; however, the significant amount of bouldery talus material at the toes of these dumps will be left to stabilize the arroyo against headcutting.

With some exceptions, all dump slopes will be reduced to a 3:1 angle, mostly by removing material for pit backfill, although, in several localities (including V,Y,I dumps), the dump toes will be pushed outward to reduce slope angle. Because of large heights and spatial considerations, dumps FD-2 and Y2 are planned to be approximately 2:1 with terraces. Figures 3 through 10 show typical cross-sectional slope geometrics for both Anaconda's plan and the Task Force alternative for comparative purposes. It is apparent from inspection of these cross-sections that on the largest most critical dumps (V, Y, I, FD-1, FD-3, South) reduction in slope to a 3:1 angle would result in approximately

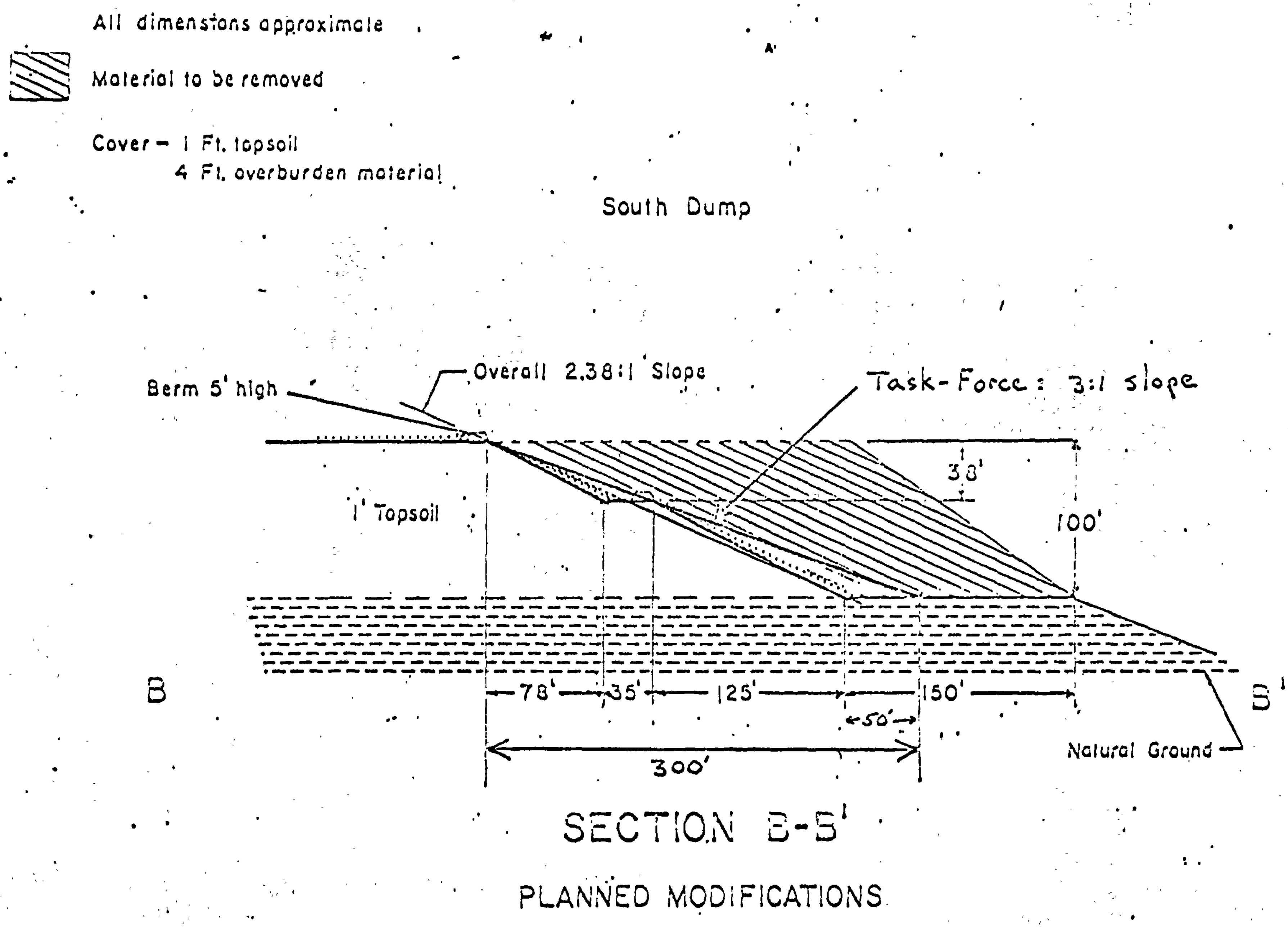
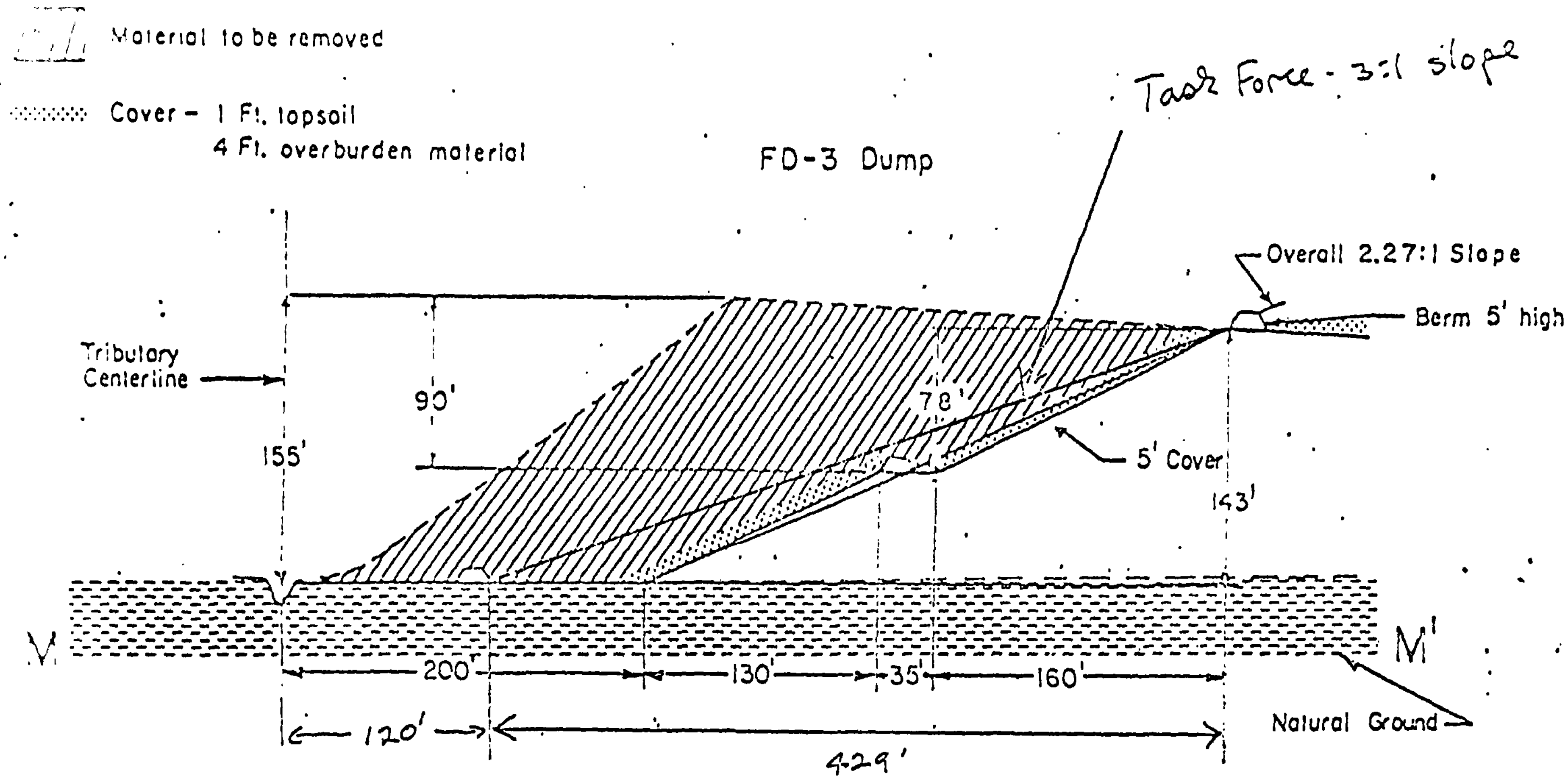


Figure 3. Anaconda and Task Force proposed slope geometrics for South dump.



SECTION M-M'

PLANNED MODIFICATIONS

Figure 4. Anaconda and Task Force proposed slope geometrics for FD-3 dump.

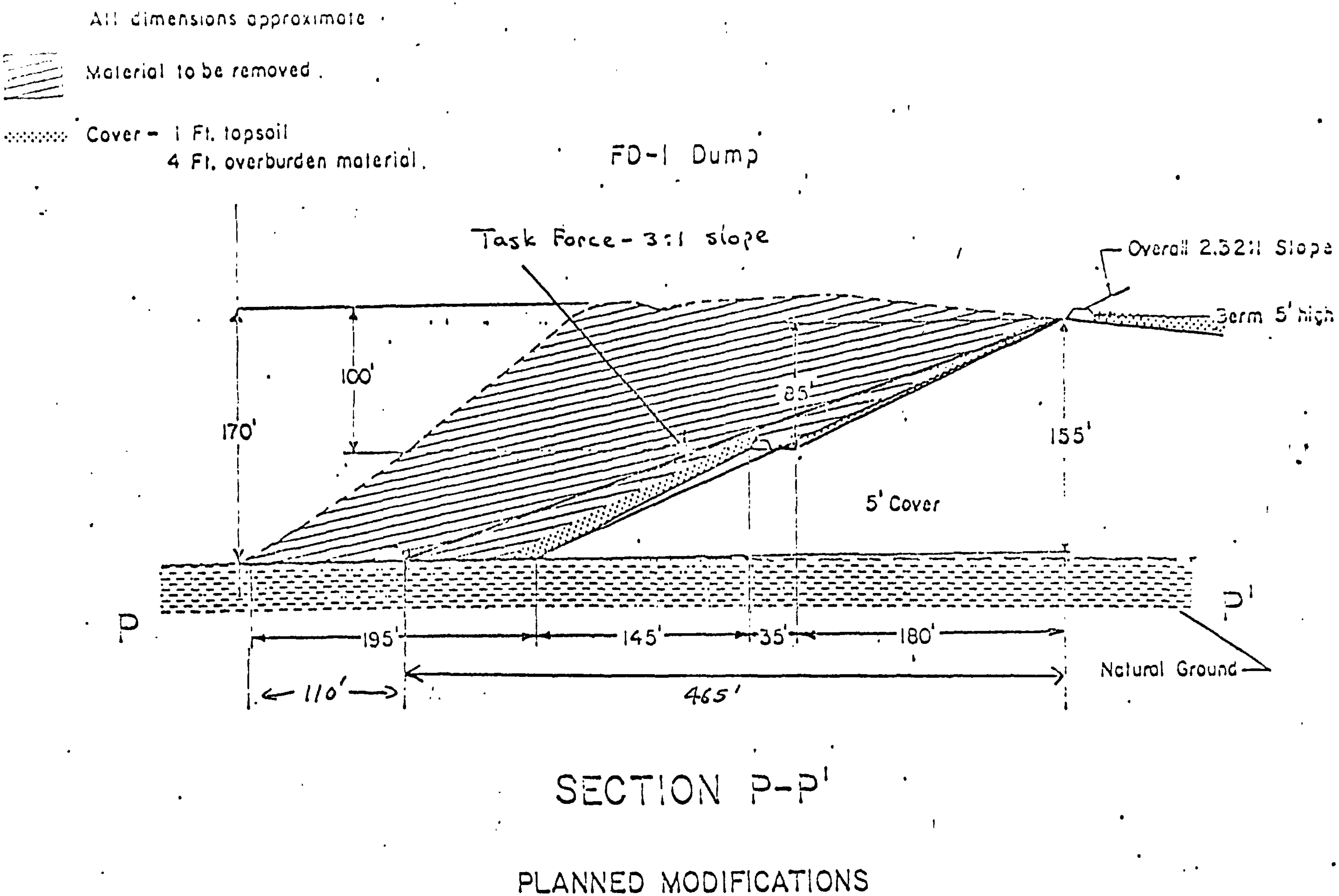


Figure 5. Anaconda and Task Force proposed slope geometrics for FD-1 dump.

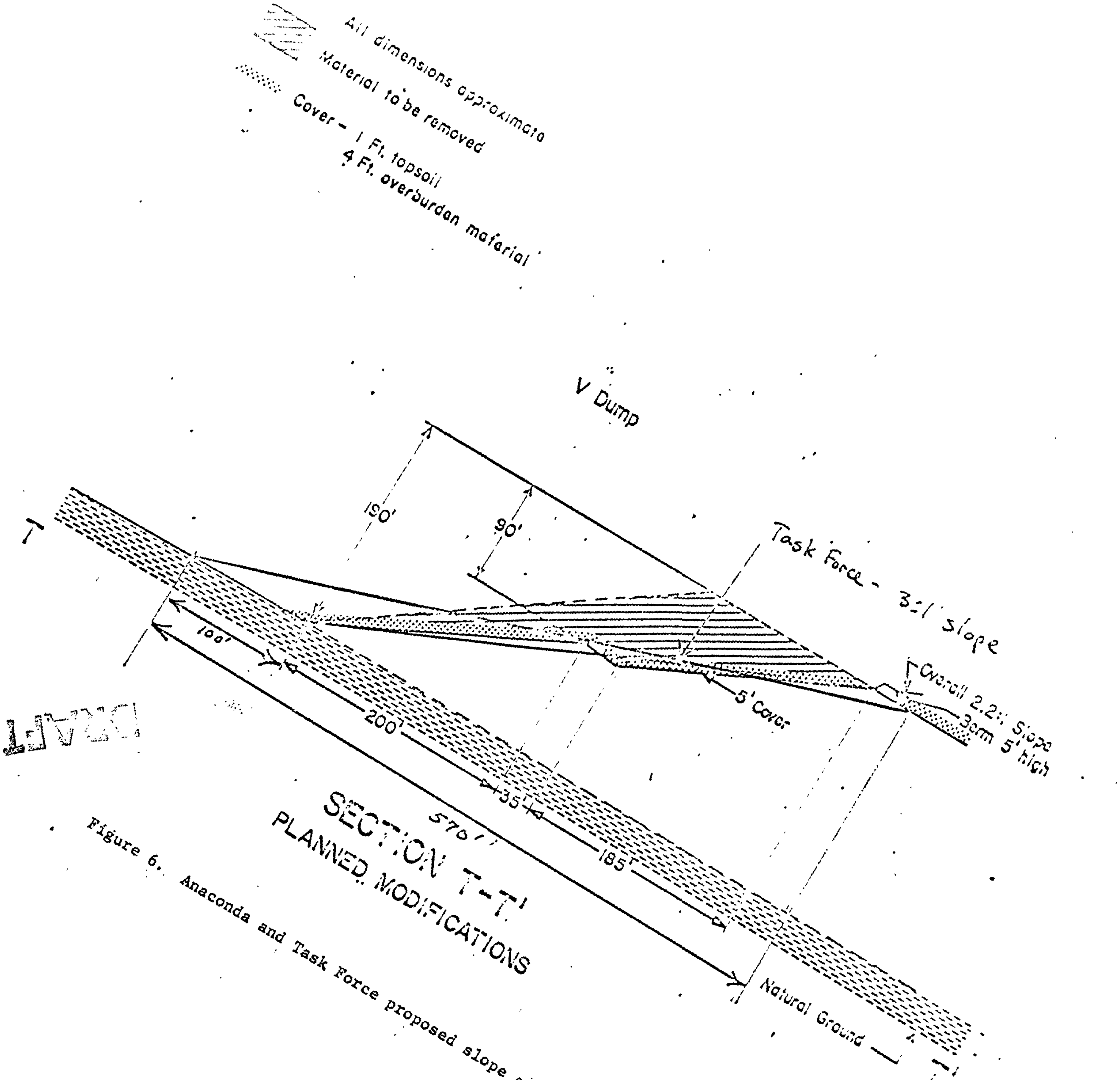


Figure 6. Anaconda and Task Force proposed slope geometrics for V dump.

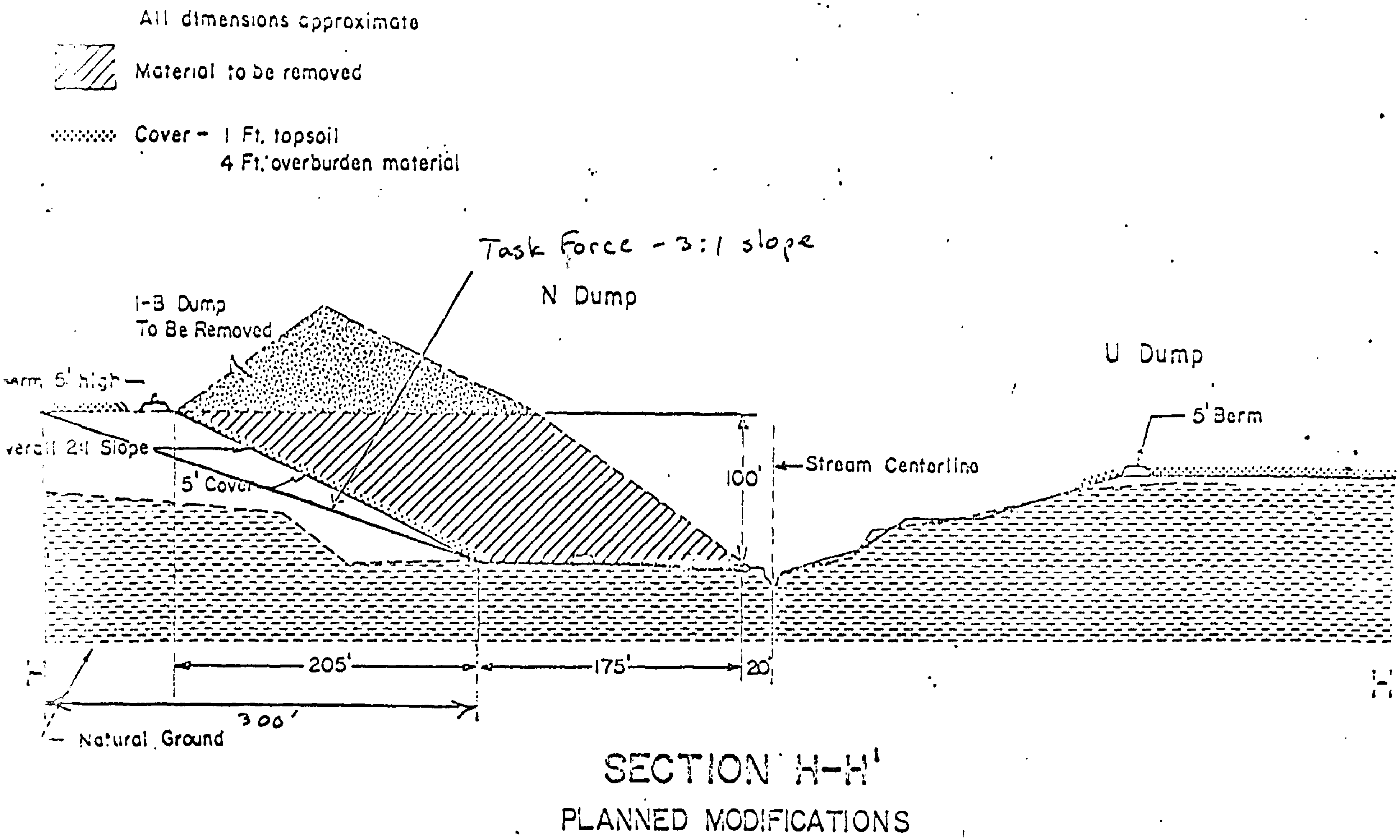
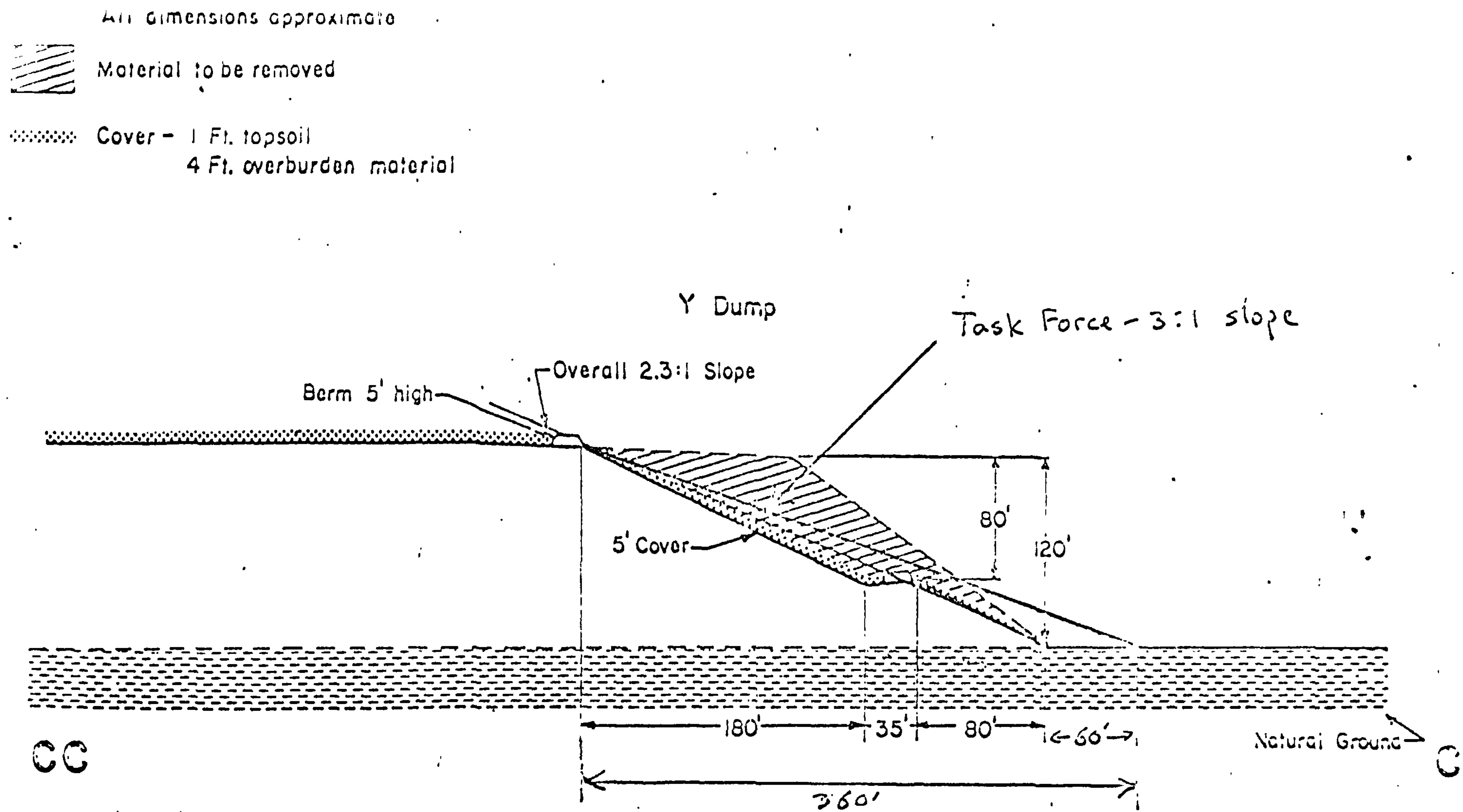


Figure 7. Anaconda and Task Force proposed slope geometrics for N dump



SECTION CC-C'

PLANNED MODIFICATIONS

Figure 8. Anaconda and Task Force proposed slope geometrics for Y dump.

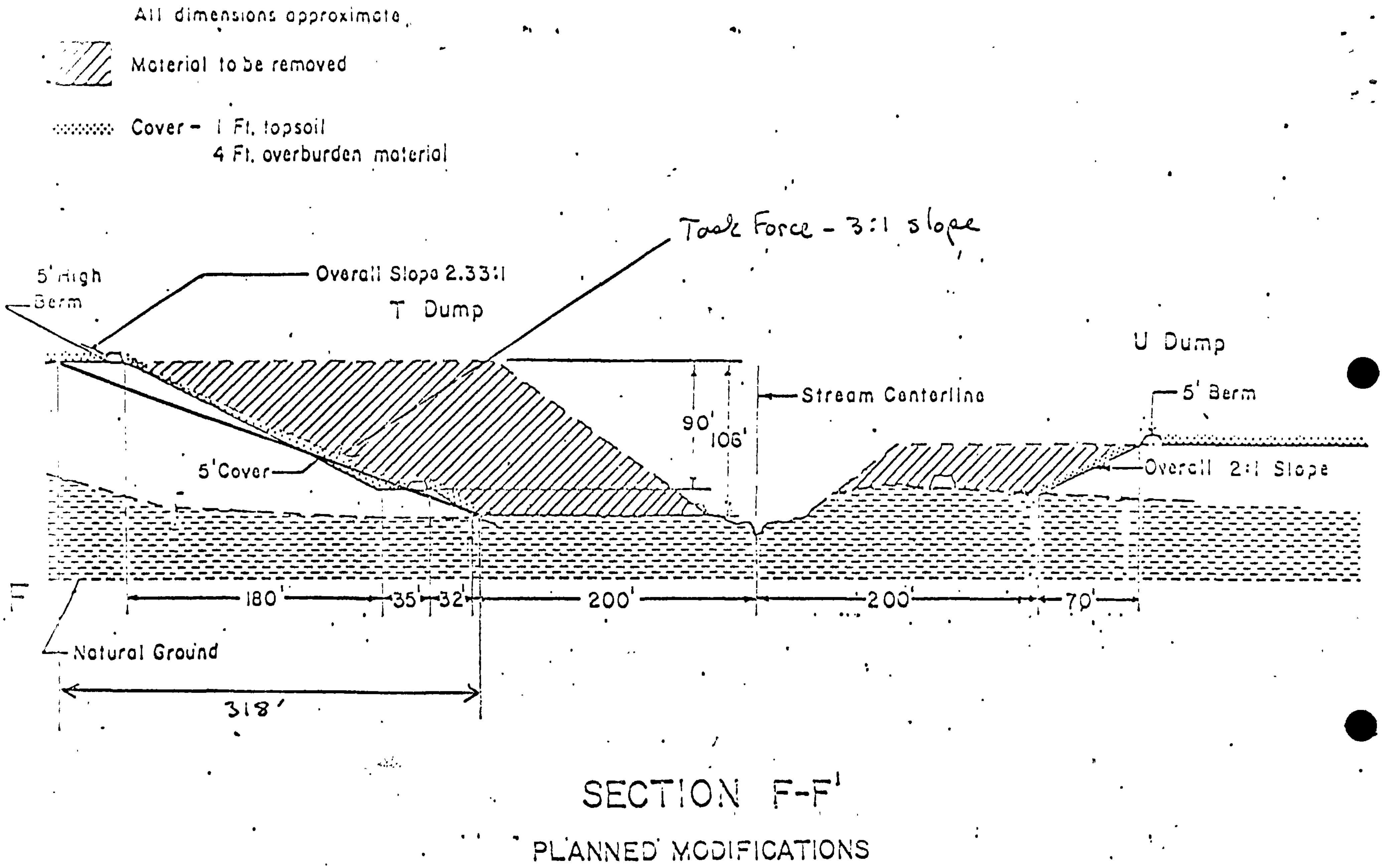


Figure 9. Anaconda and Task Force proposed slope geometrics for T dump.

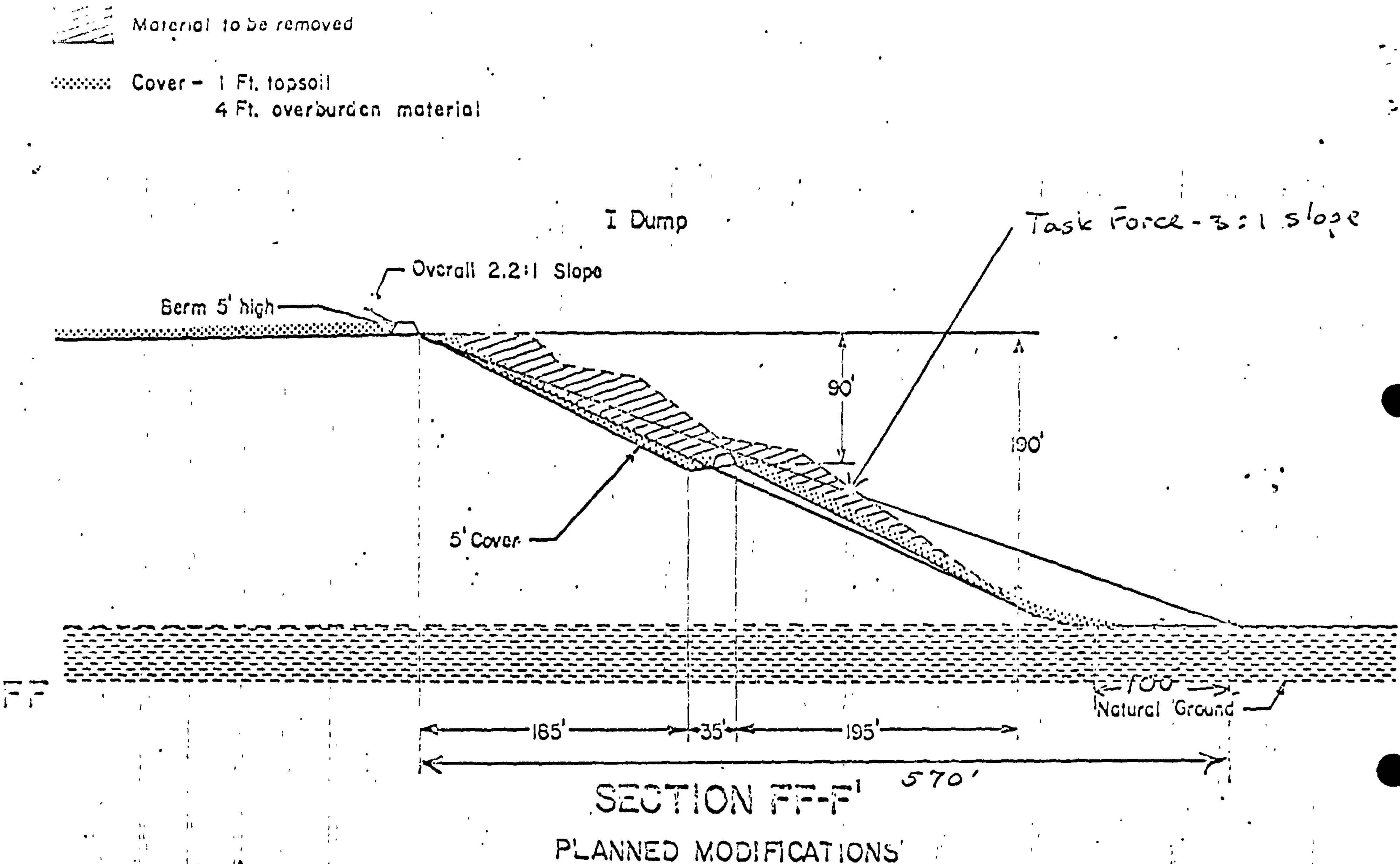


Figure 10. Anaconda and Task Force proposed slope geometrics for I dump.

equal or, in some cases, less material movement than would occur under Anaconda's plan. It is also apparent that construction of 3:1 slopes will require that the Task Force slope lengths be substantially longer than those planned by Anaconda. The longest slope under the Task Force alternative is 585 feet at I dump, and slope lengths greater than 300 feet will predominate. Five-foot high erosion control berms are planned for all dump crests and terraces and the toes of dumps along the Rio Moquino. No drainage structures will be necessary.

Dumps that contain hazardous material on their outer slopes will be covered with four feet of non-hazardous material and two feet of topsoil. Dumps that do not have an outer surface of hazardous material will be covered with two feet of topsoil. All slopes will be fertilized and contour furrowed. Bouldery material will be placed on the slopes to the greatest extent practicable. Seeding will be accomplished by rangeland drilling followed by application of two tons of crimped mulch per acre. Irrigation is not planned.

III. EROSIONAL IMPACTS

The predictive assessment of erosional impacts on reclaimed mine spoils in the western United States is a difficult task for several reasons. Firstly, erosion occurs in response to random, infrequent, and intense convective storm events which are unpredictable. Secondly, the predictive methodology for estimating sheetwash and small rill erosion - the Universal Soil Loss Equation (USLE) - was developed in humid areas with well - developed soils on slopes of less than 24 percent angle and 400 feet in length; mine waste dumps (including Jackpile-Paguate dumps) have no soils and are mostly much steeper and are longer. Thirdly, no methodology exists to predict gully erosion. Lastly, determination of sediment delivery ratios on disturbed mine watersheds is a highly subjective undertaking. In light of these problems, estimates of erosion to occur on lands disturbed by surface mining must be considered first-order approximations. These estimates should be used as general guides for assessment of alternatives and not as absolute indicators of impacts.

In this report, sheetwash erosion is estimated - using the USLE - for all external dump slopes for Anaconda's plan and the Task Force alternative. These estimates are then added to estimates of gully erosion to result in estimates of total erosion on dump slopes. The effective sediment - that sediment reaching a main-stem river - is then calculated by multiplying total erosion by sediment delivery ratios. The results are then compared and conclusions drawn concerning impacts. A description of the above-mentioned methodologies and results follows.

A. Sheetwash and Small Rill Erosion

The USLE is an empirically developed equation which relates soil loss (A) to amount, frequency, and intensity of rainfall (R), soil characteristics (K), length of slope (L), slope angle (S), vegetation or ground cover (C), and erosion control practices (P).

$$\underline{A = RK\,(LS)\,C\,P}$$

A = Soil loss in tons/acre/year

R = Rainfall factor

K = Soil erodibility

L = Slope length factor

S = Slope angle factor

C = Ground cover or vegetative factor

P = Erosion control factor

Although there are concerns over the applicability of the USLE for use on reclaimed mine lands (noted above), recent modifications in the USLE (Environmental Protection Agency, 1977) have made it a potentially valuable tool in predicting soil loss on lands disturbed by surface mining in the western United States. Specifically, factors have been included to assess the influence of dump "soils", reclamation erosion control practices, and soil cover including mulch. Application of the USLE on steep, long slopes is a concern, however, determination of factors L and S from curve extrapolations should lead to valid approximations of slope influence on erosion.

Values of USLE variables and sources of information are given in Table 1. Values of factors L and S were averaged from Anaconda (1982) cross-sections for use in obtaining LS values. A grain size analysis of Tres Hermanos Sandstone "topsoil" material was used to assist in deriving factor K; this material will be used to cover all dumps. Normally, a C factor of 0.06 would be used for slopes on which two tors per acre of crimped mulch is used (Environmental Protection Agency, 1977). However, mulch is a temporary protective measure that begins to lose its effectiveness soon after application, especially on steep, long slopes (Environmental Protection Agency, 1977). Therefore, a more realistic C factor of 0.2 was chosen for both the Anaconda and Task Force plans because this corresponds to a ground cover of 20 percent. The 20 percent cover is predicted for post-reclamation slopes based on a probable 5 to 10 percent revegetated grass cover, existence of 5 to 10 percent bouldery material and several percent of residual mulch. A C factor of 0.45 corresponds to 10 percent cover which is estimated for those post-reclamation slopes that Anaconda plans to be at 1.5:1.

The USLE - calculated values for sheetwash and small rill erosion on Jackpile-Paguate waste dumps are given in Table 2. The correlative amount of soil loss (expressed in inches lost per 100 years) is also included for each dump slope in Table 2. For Anaconda's proposal, sheetwash erosion ranges from 1.8 tons/acre/year at W dump to 33.5 tons/acre/year at P2 dump. The mean [illegible]wash erosion is 14.7 tons/acre/year. Soil loss ranges f[illegible]

TABLE 1

VALUES AND SOURCES OF VARIABLES USED IN UNIVERSAL SOIL LOSS EQUATION ANALYSIS

EQUATION: A = RK(LS) CP

VARIABLE	VALUE: Anaconda	VALUE: Task Force	SOURCE
R	25	25	U.S. Soil Conservation Service (1981)
P	1	0.65	U.S. Environmental Protection Agency (1977
C	0.2 (0.45 on some dumps)	0.2	U.S. Environmental Protection Agency (197
LS	variable (depending on dump)	variable (depending on dump)	Anaconda (1982) Utah Water Research Laboratory (1976)
K	0.085	0.085	U.S. Environmental Protection Agency (1977

Assumption for K factor derivations:

(1) Silt and very fine sand: 13.6%
(2) Sand (.1 to 2mm): 46.4%
(3) Organics: 1%
(4) Soil structure: medium or coarse granular
(5) Permeability: moderate

Table 2

USLE - calculated sheetwash and small rill erosion for dump slopes for existing conditions, Anaconda's plan and Task Force alternative. Number in parentheses gives inches of soil lost per 100 years (assuming 1750 tons = 1 acre foot). Values in tons/acre/year.

Dump	Existing	Anaconda	Task Force
I	51.6	10.6 (7")	6.9 (5")
Y2	93.5	9.3 (6")	6.1 (4")
Y	76.5	8.1 (6")	5.5 (4")
A-B	61.2	8.9 (6")	5.8 (4")
FD-3	100.3	10.0 (7")	6.4 (4")
V	105.4	11.9 (8")	7.2 (5")
U	56.1	8.1 (6")	3.3 (2")
T	76.5	9.5 (6")	5.3 (4")
N	49.9	11.5 (8")	4.7 (3")
N2	28.9	6.0 (4")	2.6 (2")
W	1.8	1.8 (1")	1.8 (1")
South	90.9	7.7 (5")	4.2 (3")
S (north)	59.5	33.5 (23")	4.7 (3")
P2	64.6	36.3 (25")	5.5 (4")
P1	34.0	19.1 (13")	3.0 (2")
L(south)	39.1	22.0 (15")	5.0 (3")
R	27.2	6.8 (5")	2.8 (2")
K	59.5	33.5 (23")	5.0 (3")
C, D, E, F, G	52.7	29.6 (20")	4.4 (3")

years at W dump to 25 inches per 100 years at P2 dump; the mean soil loss is 11 inches per 100 years.

For the Task Force alternative, sheetwash and small rill erosion ranges from 1.8 tons/acre/year at W dump to 7.2 tons/acre/year at V dump. The mean is 4.8 tons/acre/year. Soil loss ranges from 1 inch per 100 years at W dump to 5 inches per 100 years at V dump; the mean soil loss is 3 inches per 100 years.

B. Gully Erosion

Predictive methodologies similar to the USLE do not exist for use in the assessment of gully erosion to occur on reclaimed mine land. Gully erosion is a result of concentration of overland sheet flow due to minor surface irregularities, differential sheetwash erosion, pre-existence of a swale topography and other factors. As such, it is a difficult process to predict in a quantitative fashion.

Smith (1981) measured the amount of material removed by gully erosion on 6 waste dump slopes at the Jackpile-Paguate Mine. The total amount of eroded material and that amount eroded per year by gullies is given in Table 3. The mean amount of gully erosion per year for these dump slopes is 15.58 tons/acre/year. In the absence of more data, this figure is taken to be the existing rate of gully erosion for dump slopes. Modification and reclamation of dump slopes will reduce the existing rate of gully erosion. Reduction of slope angle and length and application of erosion control practices are seen as the most effective modifications that will reduce gully erosion. Use of mulch and other cover techniques, although effective in reducing sheetwash erosion, will not be effective in reducing gully erosion since concentration of flows would easily displace such material. Therefore, in this report, a prediction of gully erosion on dump slopes is arrived at by reducing the existing gully erosion rate (15.58 tons/acre/year) by the amount of reduction in the LS and P factors of USLE under the Anaconda and Task Force plans. Table 4 summarizes the LS and P reductions and Table 5 shows estimated rates of gully erosion under both plans.

Table 3

Gully erosion measured at six waste dump slopes*

Dump	Amount Eroded (Tons/Acre)	Approximate Age of slope	Amount Eroded (Tons/Acre/Year
Y	561	1955	21.6
Y2	172	1962	8.6
V	162	1977	40.5
FD-3	16	1979	8.0
J	27	1977	6.75
T	24	1978	8.0
			MEAN = 15.58

* Figures show total material lost from waste dump slopes computed by U.S. Soil Conservation Service (1981) equations.

Table 4

LS factors for existing conditions, Anaconda's plan, and Task Force plan showing fraction of existing conditions LS in parentheses. P factor summarized below*

Dump	Existing	Anaconda	Task Force
I	30	25 (.83)	25 (.83)
Y2	55	22 (.4)	22 (.4)
Y	45	19 (.42)	20 (.44)
A-B	36	21 (.58)	21 (.58)
FD-3	59	23.5 (.43)	23 (.39)
FD-1	55	25 (.45)	24 (.44)
V	62	28 (.45)	26 (.42)
U	33	19 (.58)	12 (.36)
T	45	26.5 (.58)	19 (.42)
N	29	27 (.93)	17 (.59)
N2	17	14 (.82)	9.5 (.56)
South	54.5	18 (.33)	15 (.28)
S(north)	35	35 (1.0)	17 (.49)
R	16	16 (1.0)	10 (.78)
P2	38	38 (1.0)	20 (.53)
L(south)	23	23 (1.0)	18 (.78)
PI	20	20 (1.0)	11 (.55)
K	35	35 (1.0)	18 (.51)
C, D, E, F, G	31	31 (1.0)	16 (.52)

* P Factor:

Existing: 1.0
Anaconda: 1.0
Task Force: 0.65

Table 5

Gully erosion predicted to occur on waste dump slopes under Anaconda and Task Force plans. Values in tons/acre/year. Existing conditions = 15.58 tons/acre/year due to gully erosion.

Dump	Anaconda	Task Force
I	12.9	12.9
Y2	6.3	6.2
Y	6.5	6.9
A-B	9.0	9.0
FD-3	6.7	6.1
FD-1	7.0	6.9
V	7.0	6.5
U	9.0	5.6
T	9.0	6.5
N	14.5	9.2
N2	12.8	8.7
South	5.1	4.3
S(north)	15.6	7.6
P2	15.6	8.3
P1	15.6	8.6
L(south)	15.6	12.2
R	15.6	9.8
K	15.6	7.9
C, D, E, F, G	15.6	8.1

C. Total Erosion

The computed values for sheetwash and small rill erosion were added to the estimated rate of gully erosion for each dump slope to arrive at predicted values for total erosion. The results - including percent reduction from existing conditions - are shown in Table 6. For existing conditions, the range in total erosion is 42.8 to 121.0 tons/acre/year, and the mean total erosion is 79.4 tons/acre/year.

If Anaconda's plan were implemented, the total erosion from waste dump slopes would range from 12.8 to 51.9 tons/acre/year with a mean of 26.7 tons/acre/year. Anaconda's proposed techniques for slope reclamation would reduce erosion to 19 to 88 percent of existing rates; the mean reduction from existing erosion rates is 61 percent.

If the Task Force proposal were implemented, the total erosion from dump slopes would range from 8.5 to 19.8 tons/acre/year with a mean of 13.2 tons/acre/year. The Task Force plan would reduce erosion to 63 to 92 percent of existing rates with a mean reduction of 82 percent.

D. Effective Sediment

Effective sediment is that eroded detritus that reaches a main-stem river, in this case, the Rio Paguate or Rio Moquino. It is calculated by multiplying total erosion (units: tons/acre/year) by the amount of dump slope acres to result in amount of material (tons/year) eroded from each slope. This amount is then multiplied by a sediment delivery ratio, which is the estimated fraction of sediment eroded from waste slopes to reach the main-stem river. The sediment delivery ratio is determined by estimating the amount of material that will be stored in alluvial fans, overbank deposits, and channel bars or trapped behind erosion control berms or dams.

Sediment delivery ratios and amounts of slope acres are given in Tables 7 and 8, respectively, and effective sediment is given in Table 9. Approximately

Table 6

Total erosion in tons/acre/year on waste dump slopes from existing conditions, Anaconda's plan and Task Force plan. Percent reduction from existing erosion rate shown in parentheses.

Dump	Existing	Anaconda	Task Force
1	67.2	23.5 (65%)	19.8 (71%)
2	109.1	15.6 (86%)	12.3 (89%)
	92.1	14.6 (84%)	12.4 (87%)
-B	76.6	17.9 (77%)	14.8 (81%)
D-3	115.9	16.7 (86%)	13.1 (89%)
D-1	109.1	17.6 (84%)	13.5 (88%)
	121.0	18.9 (84%)	13.7 (89%)
	71.7	17.1 (76%)	8.9 (88%)
	92.1	18.5 (80%)	11.8 (87%)
	65.5	26.0 (60%)	13.9 (79%)
2	44.5	18.8 (58%)	11.3 (75%)
outh	106.5	12.8 (88%)	8.5 (92%)
(north)	75.1	49.1 (35%)	12.3 (84%)
	42.8	22.4 (48%)	12.6 (71%)
2	80.2	51.9 (35%)	13.8 (83%)
(south)	46.2	37.6 (19%)	17.2 (63%)
I	49.6	34.7 (30%)	11.6 (77%)
	75.1	49.1 (34%)	12.9 (83%)
, D, E, F, G	68.3	45.2 (34%)	12.5 (82%)

Table 7

Sediment delivery ratios and explanations for waste dump slopes.

Dump	Ratio	Explanation
FD-2,C, D, E, F, G, L (south)	0.0	blocked drainage
S (north)	0.5 (Anaconda)	Drains directly into arroyo with short course to Rio Moquino; alluvial fan deposition may store about 50% of sediment.
	0.05 (Task Force)	Toe berm should store about 95% of sediment.
T, N, N2, U	0.05	Toe berms should store about 95% of sediment.
Y, Y2, I,	0.15 (Anaconda)	Alluvial fans and terraces should store about 85% of sediment.
	0.05 (Task Force)	Large toe berm and depression should contain most sediment.
V	0.15	Alluvial fan, terraces and furrows should store sediment.
South, K	0.1	Long arroyo length will provide overbank and sandbar storage of about 90 percent of sediment.
FD-3, FD-1 A-B	0.05	Toe berms and dams should store about 95% of sediment.
R, P1, P2	0.2	Alluvial fan deposition should contain about 80 percent of sediment.

Table 8

Dump slope acreage for Anaconda and Task Force plans.

Dump	Anaconda	Task Force
I	24	34.1
Y2	6.5	6.5
Y	21	26.7
A-B	22	22
FD-3	9	13.5
FD-1	15.75	23.1
V	25	35.9
U	13.5	19.5
T	10.5	17.7
N	10	14.2
N2	1.5	2.1
South	24	30.9
S(north)	5	10
R	3.25	4.9
P2	3.25	6.5
L(south)	5	10
P1	2.75	5.5
K	7	14
C, D, E, F, G	5.5	11

Table 9

Effective sediment from waste dump slopes in tons/year. Amount of material of 0 to 0.02% U_3O_8 reaching Rio Moquino or Rio Paguate each year is given in parentheses.

Dump	Anaconda	Task Force
I	84.6 (4.2)	33.8 (1.7)
Y2	15.2 (0.8)	4.0 (0.2)
Y	46.0 (2.3)	16.6 (0.8)
A-B	19.7 (1.0)	16.3 (0.8)
FD-3	7.5 (0.4)	8.8 (0.4)
FD-1	13.9 (0.7)	15.6 (0.8)
V	70.9 (3.5)	73.8 (3.7)
U	11.5 (0.6)	8.7 (0.4)
T	9.7 (0.5)	10.4 (0.5)
N	13.0 (0.6)	9.9 (0.5)
N2	1.4 (.1)	1.2 (.1)
South	30.7 (1.5)	26.3 (1.3)
S(north)	122.8 (6.1)	6.2 (0.3)
R	14.6 (0.7)	12.3 (0.6)
P2	33.7 (1.7)	17.9 (0.9)
L(south)	0 (0)	0 (0)
P1	19.1 (1.0)	12.8 (0.6)
K	34.4 (1.7)	18.1 (0.9)
FD-2, C, D, E, F, G	0 (0)	0 (0)
TOTALS	548.7 (27.4)	292.7 (14.6)

550 tons of sediment (under Anaconda's plan) or 300 tons of sediment (under the Task Force plan) would annually reach the Rio Moquino or Rio Paguate. In the absence of details of radiological content of each dump, the amount of uraniferous material in the effective sediment was calculated by multiplying the effective sediment by 0.05, since a stripping ratio of roughly 20 (overburden) to 1 (Jackpile sandstone) was used during mining. This calculation gives an estimate of the amount of material of 0 to .02% U 0 reaching the main-stem rivers each year. For Anaconda's plan, roughly 27 tons of material from 0 to 0.02% U 0 would annually reach these rivers, while, under the Task Force plan, about 15 tons of sediment of this grade would annually reach the rivers.

IV. DISCUSSION

It is apparent that, based on the above calculations, Anaconda's plan would result in significantly more erosion than would occur under the Task Force plan. The calculations reveal that the major causes of this difference are: 1) as documented by the slightly lower Task Force LS values, the Task Force reduction in slope angle is more effective in inhibiting erosion than Anaconda's emphasis on reduction in slope length, and, more importantly, 2) the Task Force technique of contour furrowing, which is not proposed by Anaconda, inhibits erosion effectively.

However, upon examination of the total erosion and effective sediment tables (Tables 6 and 7), it is clear that the dumps that Anaconda has declared reclaimed (C, D, E, F, G, K, L, P1, P2, S-north) will be sources of an inordinate amount of eroded material. This is due simply to the fact that steep slopes (1.5:1 - high LS values) will inhibit mulch retention and vegetative establishment (high C values). The mean of total erosion on these dump slopes under Anaconda's plan is estimated at 44.6 tons/acre/year while, for the rest of Anaconda - planned slopes, the mean is estimated at 18.5 t figure close to the Task force plan of 13.2 tons/acre/year. Moreover, about 38 percent of the effective sediment comes from these "reclaimed" dumps that comprise approximately 9 percent of slope acreage. By incorporating slope modifications to these dumps similar to those proposed for other dumps, it is expected that erosional impacts of Anaconda's plan could be reduced significantly. In addition, berming of the toes of dumps S and P2 would greatly reduce effective sediment contributions.

There are two general types of impacts resulting from dump slope erosion at the Jackpile-Paguate Mine. Firstly, the impacts of total erosion rates are possible dissection of the slope with resultant loss of grazing land and exposure of radiologically hazardous material due to gullying. Secondly, the impacts of effective sediment rate are possible radiological contamination of water and subsequent ingestion by domestic animals.

Total erosion rates for Anaconda's plan are estimated to be roughly twice those that would occur under the Task Force plan. However, sheetwash and small rill induced soil loss - 11 inches per 100 years for Anaconda's plan and 3 inches per 100 years for the Task Force plan - is predicted to be relatively minor. But, due to steep slopes planned by Anaconda, the potential for slope dissection and loss of grazing land by gullying would appear significant. Anaconda proposed rock-lined chutes to drain water off slopes in order to reduce the high dissection potential. However, Soil Conservation Service, U.S. Geological Survey (WRD), and MMS personnel have determined that these structures would have high maintenance costs and that their stability is questionable. Failure of these structures and resultant gullying is considered probable.

The Task Force alternative was designed so that relatively gentle slopes and contour furrowing would combine to retain water and reduce dissection potential so that maintenance - dependent drainage structures would be unnecessary. Field examination of reclaimed slopes at the McKinley Coal Mine near Gallup indicates that slopes of 3:1 angle are stable against dissection for slope lengths longer than about 570 feet without drainage structures. This observation and the calculations of this report suggest that there is not a high potential for gully - induced loss of grazing land and exposure of hazardous material under the Task Force plan.

Effective sediment rates for Anaconda's plan would be roughly twice those that would occur under the Task Force plan. However, in view of the high existing effective sediment rate (about 10 to 17 times that of the Anaconda or Task Force plans) and resultant lack of significant contamination of surface water, it is considered that the much lower effective sediment rates of both plans would not lead to surface water contamination impacts.

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V. CONCLUSIONS

The major conclusions of this analysis are:

1. The mean of total erosion that would occur on waste dump slopes under Anaconda's plan is approximately 26 tons/acre/year and the mean reduction from existing rates of total erosion is 61 percent. The mean of total erosion that would occur under the Task Force plan is approximately 13 tons/acre/year and the mean reduction from existing rates is 82 percent. These figures compare to soil erosion rates of 1.5 to 9.0 tons/acre/year on natural terrain near the mine-site.

2. For Anaconda's plan, approximately 27 tons of material of 0 to 0.02% U O would annually reach the Rios Moquino and Paguate, while, for the Task Force plan, about 15 tons of sediment of this grade would annually reach the rivers.

3. For Anaconda's plan an inordinate amount of effective sediment and total erosion would occur on steep (1.5:1) dump slopes that Anaconda has designated reclaimed. Modification of these slopes using designs similar to those proposed for other Anaconda slopes would reduce erosion to levels close to those predicted for the Task Force plan.

4. Surface water contamination resulting from uraniferous sediment reaching the main-stem rivers is predicted to be negligible.

5. For both plans, erosional impacts of sheetwash and small rill erosion would appear to be minor. However, implementation of Anaconda's dump slope reclamation techniques would result in a significant potential for slope dissection and loss of grazing land due to failure of rock-lined drainages and subsequent gullying. In contrast, implementation of the Task Force plan is predicted to result in minor gullying due to the effects of gentler slopes and contour furrow techniques.

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